Attachment 1

Earthquake Ground Motion Assessment

EARTHQUAKE GROUND MOTION ASSESSMENT
In-Delta Water Storage Risk Assessment
Delta Wetland, California

INTRODUCTION

This technical memorandum presents the results of a study conducted by URS to assess potential future earthquake ground motions at the In-Delta water storage facility located near San Francisco Bay region, California. The water storage facility will be constructed by converting two existing islands (Bacon Island and Webb Track) into water storage islands. Perimeter embankments will be built to impound the reservoir water. This study was conducted to address comments on developing site-specific ground motions for the reservoir islands and to allow a more complete seismic hazard characterization at the reservoir islands.

OBJECTIVE

The approach taken for this study was to conduct a probabilistic ground-motion analysis to assess the probabilities of exceeding various ground motion intensities at the proposed facility. Specifically, the available geologic and seismologic data, including evaluations previously performed for nearby locations by the Bureau of Reclamation (LaForge et al. (2002) for the Martinez and Contra Loma Dams, Ake, et al. (1999) for the Tracy Fish Test Facility) and Calfed (1998) for the Delta Wetland, were reviewed to evaluate and characterize potential seismic sources and the likelihood of earthquakes of various magnitudes occurring on those sources.

The following sections present the methodology used for the probabilistic seismic hazard analysis, the seismic source characterization, the attenuation relationships used, and the results of analysis.

PROBABILISTIC GROUND-MOTION ANALYSIS

Methodology

The probabilistic analysis is based on the methodology proposed by Cornell (1968) and includes some of the most recent developments in the model. Assuming that earthquake occurrences are Poisson processes, the probability that a ground motion parameter ‘Z’ (peak and response spectral accelerations) at the site exceeds a specific value ‘z’, in a time period ‘t’, is given by:

$$p(Z>z) = 1 - e^{-\varphi(z)\,t}$$

where φ (z) is the annual mean number of seismic events in which the ground motion parameter ‘Z’ at the site exceeds the value ‘z’ (i.e., annual frequency of exceedance). φ (z) can be calculated as follows:

$$\varphi(z) \quad = \quad \int_I \int_J \alpha_{m0} \bullet f(m_i) \bullet p(R = r_j \backslash m_i) \bullet p(Z > z \backslash m_i r_j)$$

where:

α_{m0} = annual mean number of seismic events with magnitudes greater than m_0 ,
$f(m_i)$ = probability density function for seismic events of magnitude m_i ,
$p(R=r_j \backslash m_i)$ = probability that given the occurrence of an earthquake of magnitude m_i, the source-to-site distance is r_j ,
$p(Z > z \backslash m_i, r_j)$ = probability that given the occurrence of an earthquake of magnitude m_i at the source-to-site distance of r_j, the ground motion parameter 'Z' at the site exceeds a specific value of z.

The total annual frequency of exceedance for ground motion parameter 'Z' at the site (i.e., total hazard) is then obtained by summing the hazards from all seismic sources:

$$\varphi_t(z) \quad = \quad \sum_N \varphi_n(z)$$

where N is the number of seismic sources considered in the study.

The uncertainties associated with seismic source parameters (geometry, location and recurrence parameters) were incorporated in the analysis using the logic tree approach, as shown in Figure 2.

Seismic Source Characterization

Two types of earthquake sources are characterized and used in the analysis. They are: 1) fault sources and areal (random) source zones. Fault sources are modeled as three-dimensional fault surfaces and details of their behavior are incorporated into the source characterization. Areal source zones are regions where earthquakes are assumed to occur randomly within the souce boundaries. The detailed discussion of the seismic source characterization is presented in Appendix A. Figure 1 shows the approximate locations of the seismic sources.

Seismic sources are modeled in the hazard analysis in terms of geometry and earthquake recurrence. For fault sources, three recurrence models were used: Characteristic, truncated exponential and maximum magnitude models. They were assigned the following weights: 0.3 for characteristic model, 0.1 for truncated exponential model, and 0.6 for maximum magnitude model. For areal source zones, only the truncated exponential recurrence model was used in the analysis. Figures 3 and 4 present the recurrence rates, as a function of magnitude, calculated for the seismic sources.

Attenuation Relationships

Earthquake ground motion attenuation relationships used in this study are those developed for deep stiff soil sites by Abrahamson and Silva (1997), Sadigh, et al. (1997), Boore et al. (1997) and Campbell (1997). These relationships were developed on the basis of statistical analyses of ground motions recorded during past earthquakes having similar tectonic environment with that of western United States. These empirical attenuation relationships were weighted equally.

For Boore et al. (1997) relationships, a shear-wave velocity of 300 m/sec was used. This shear-wave velocity value was selected based on the results of a field measurement conducted at the nearby location (Boulanger et al.,1997).

Hazard Results

The hazards were computed for a point located approximately in the middle of the Bacon Island. Computed seismic hazard curves that relate the amplitudes of peak ground acceleration and spectral accelerations to the annual frequencies of exceedance of those amplitudes are shown in Figure 5 and 6, for peak ground acceleration and 1-0-sec spectral acceleration, respectively. Also plotted on these figures are the contribution curves from the various seismic sources considered in this study. As can be seen from these figures, the hazard at the project site is dominated by the nearby Mt. Diablo Thrust, and to a lesser degree, the Coast Range random zone. The San Andreas, Hayward and Calaveras fualts also contribute to the long-period motions, as shown in Figure 4 for the 1-0 sec. Spectral acceleration.

The 5% damped equal-hazard response spectra for the 43-, 100-, 200-, 475-, 1,000-, and 2,500- year return periods were developed using these computed hazard curves, and they are shown in Figures 7. The spectral values at selected periods are listed in Table 1.

Table 1. Calculated Acceleration Spectral Values at Selected Periods

	5% Acceleration Response Spectral Value, g			
Period, sec	43-year return period	100-year return period	200-year return period	475-year return period
PGA	0.14	0.20	0.26	0.33
0.075	0.21	0.30	0.39	0.51
0.10	0.25	0.35	0.46	0.62
0.20	0.32	0.46	0.59	0.80
0.30	0.32	0.46	0.59	0.80
0.50	0.27	0.38	0.49	0.68
1.0	0.16	0.24	0.31	0.42
2.0	0.09	0.13	0.17	0.24

COMPARISON WITH PREVIOUS STUDY

The results of the current study were compared with those calculated by Calfed (1998) in Table 2 below. It can be seen that the PGAs calculated using current model are about 15% to 35% higher than those calculated by Calfed (1998).

Table 2. Comparison with Results of Calfed (1998) Study

	Spectral Acceleration in g							
	43-yr return period		100-yr return period		200-yr return period		475-yr return period	
Period	Current study	Calfed study	Curren t study	Calfed study	Current study	Calfed study	Current study	Calfed study
PGA	0.14	0.114	0.20	0.175	0.26	0.19	0.33	0.25

REFERENCES

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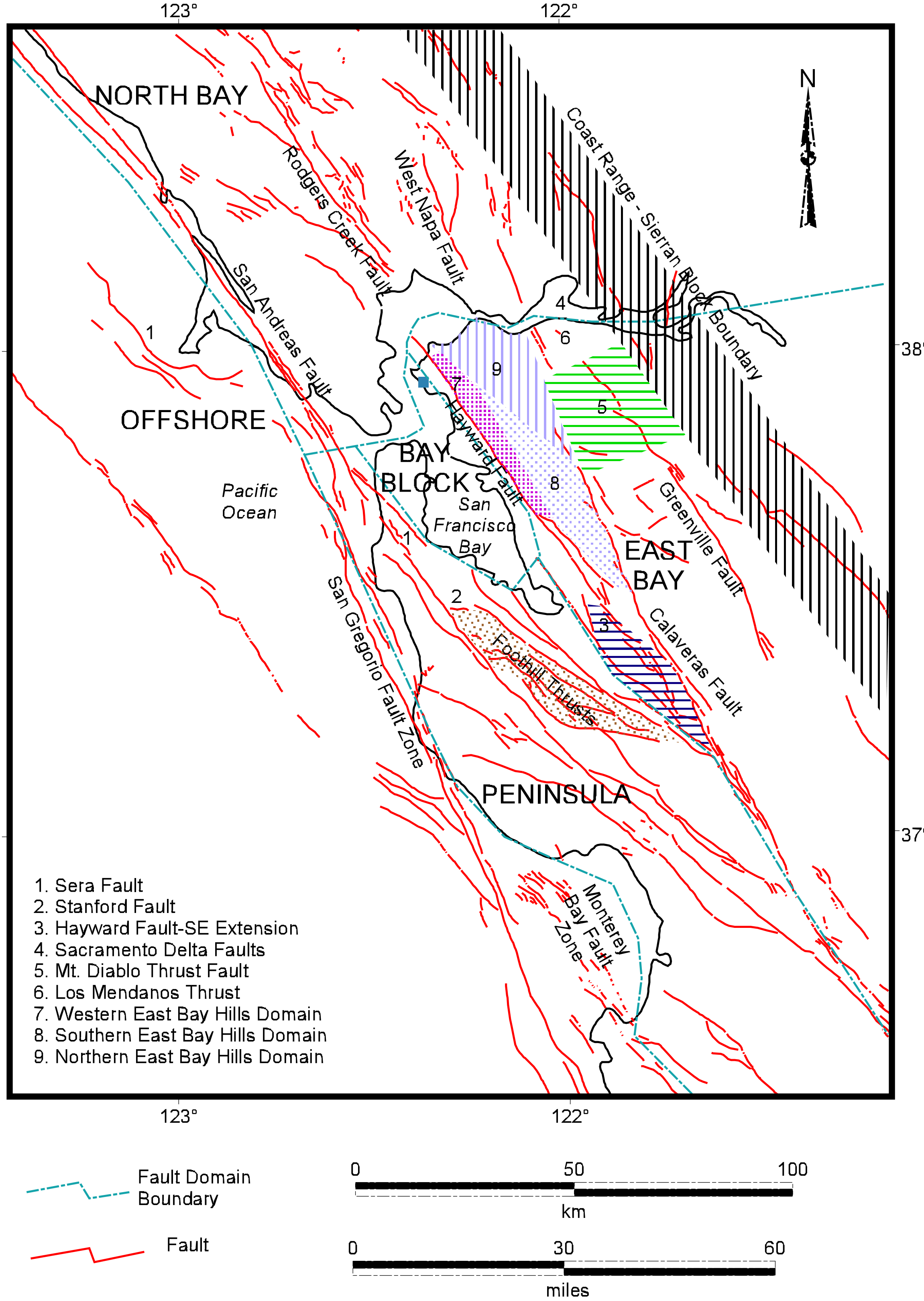
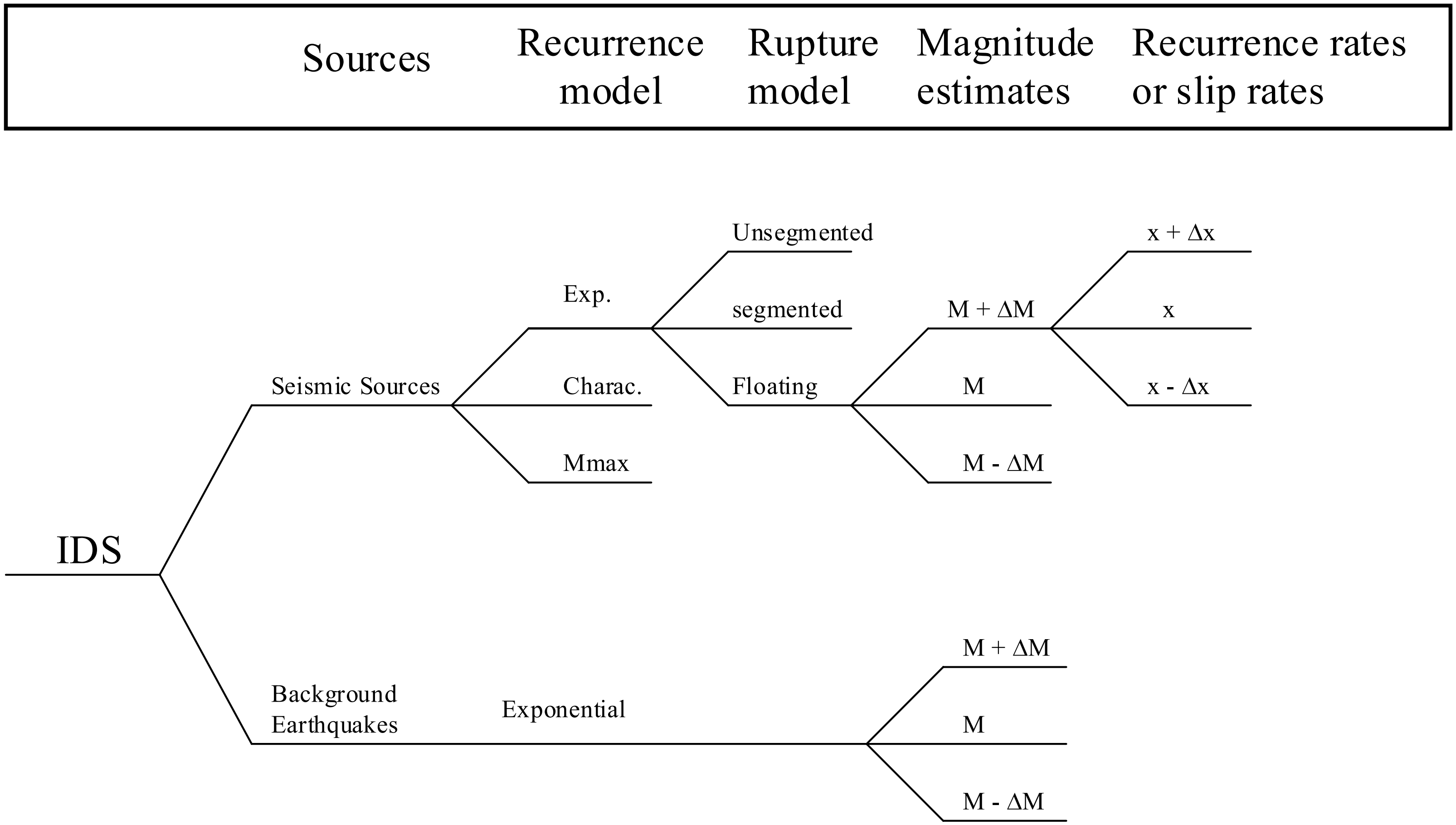
Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi, F., and Youngs, R.R., 1997, Attenuation relationships for shallow crustal earthquakes based on California strong motion data, Seismological Research Letters, Vol. 68, No. 1, January.



URS	Project No. 26814105	MAJOR ACTIVE FAULTS	Figure 1
	In-Delta Storage		



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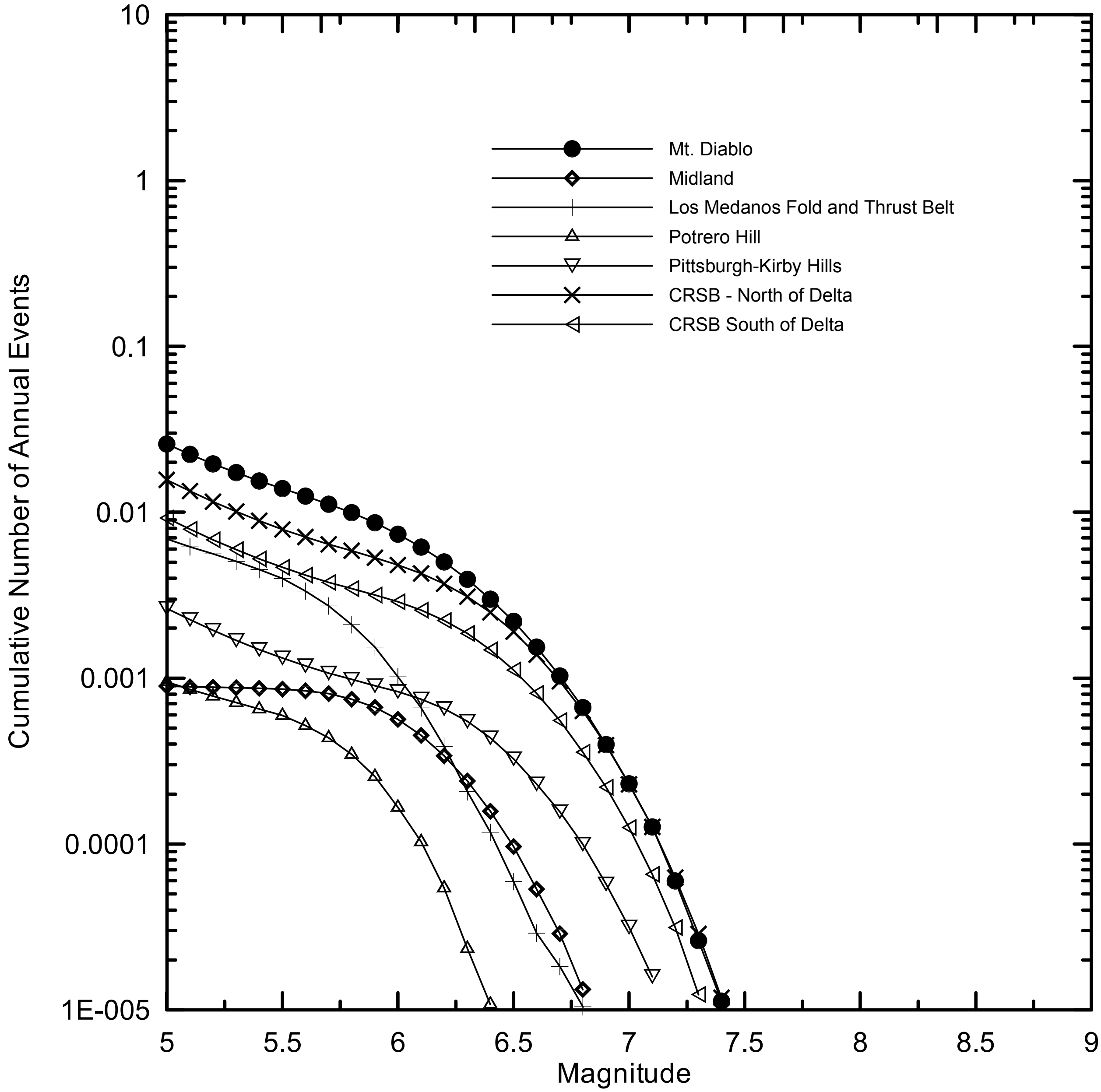
DELTA WETLANDS PROJECT
IN-DELTA STORAGE
FEASIBILITY STUDY

Logic Tree for Fault Characterization Model

Figure 2



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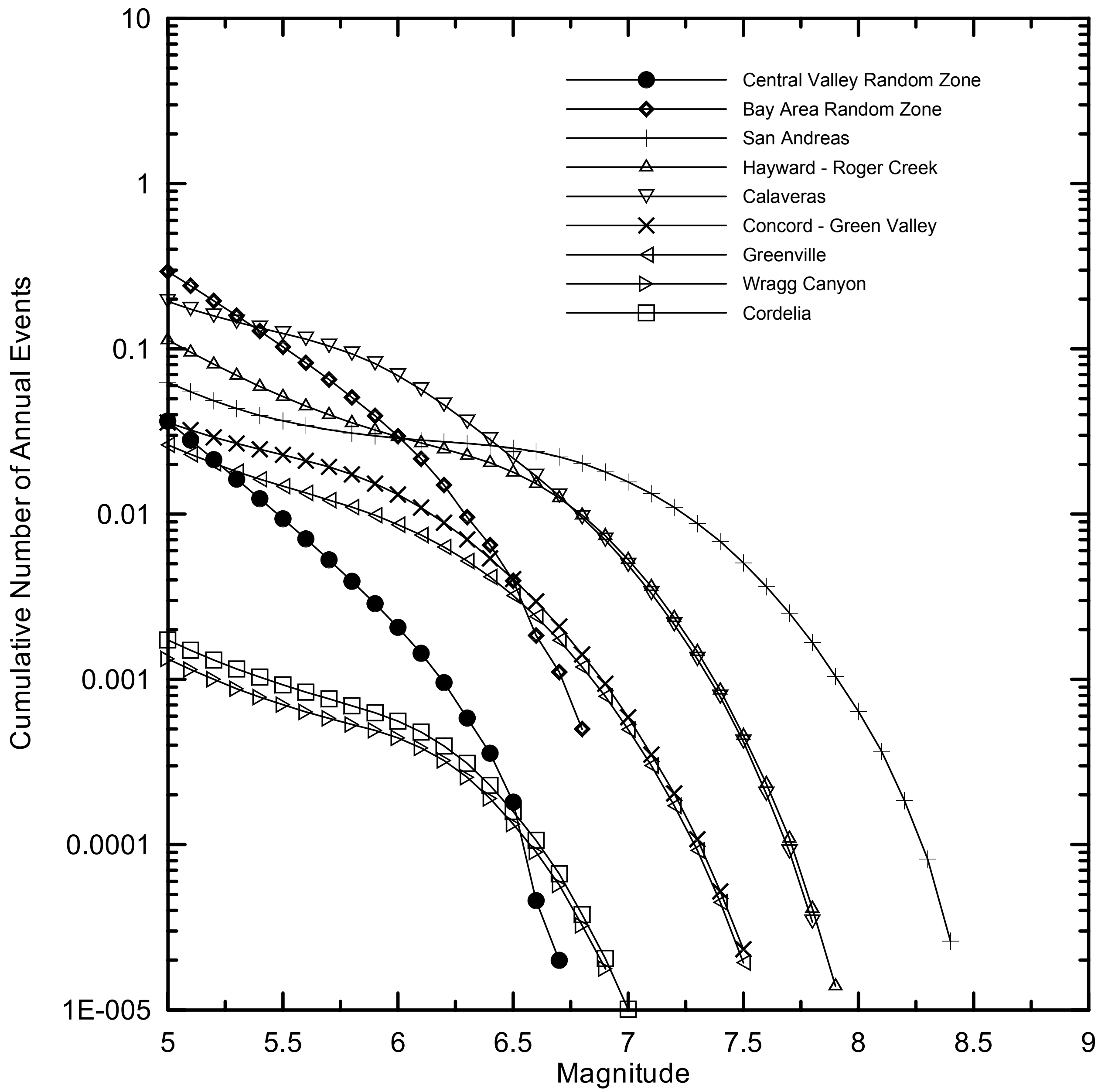
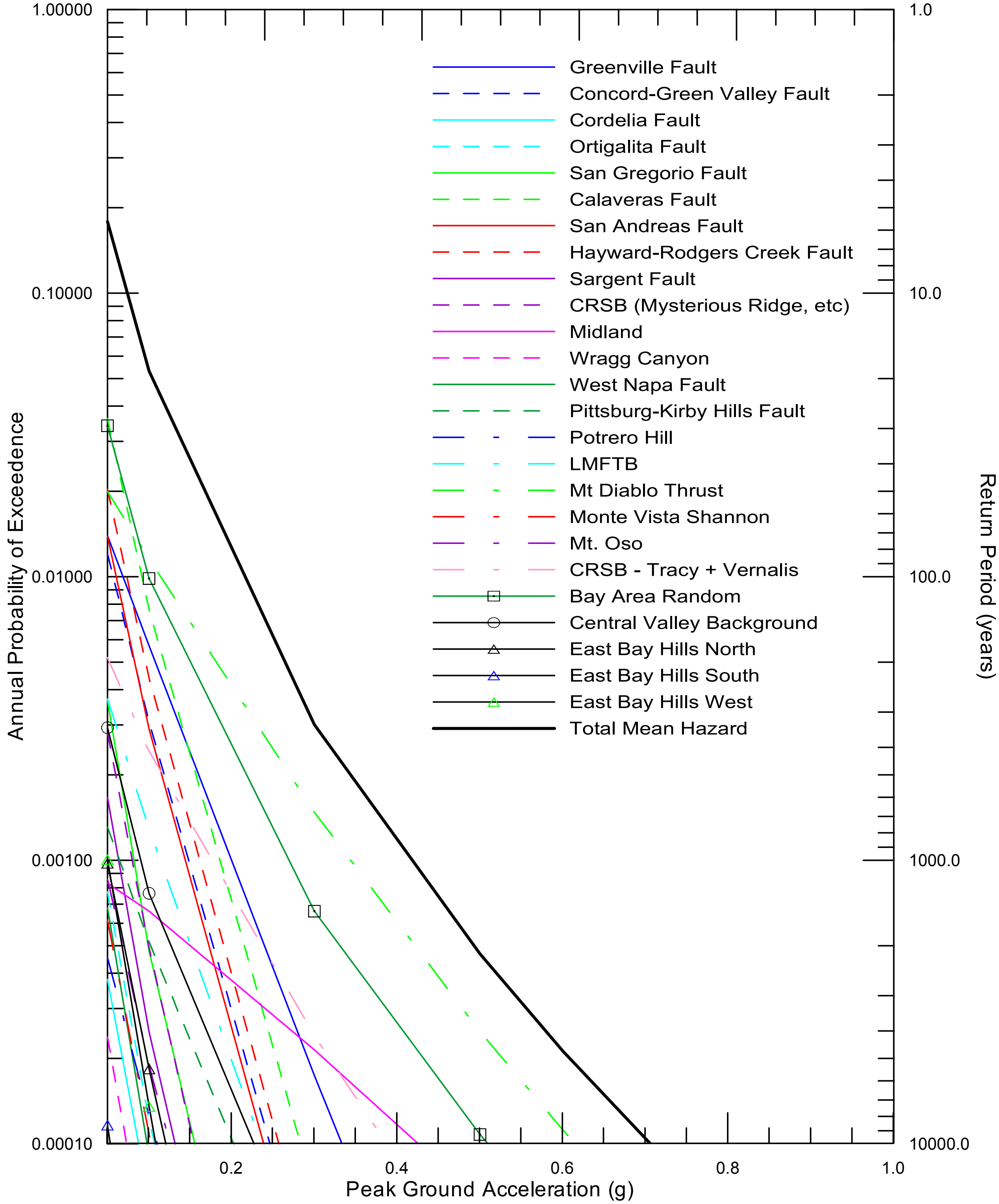
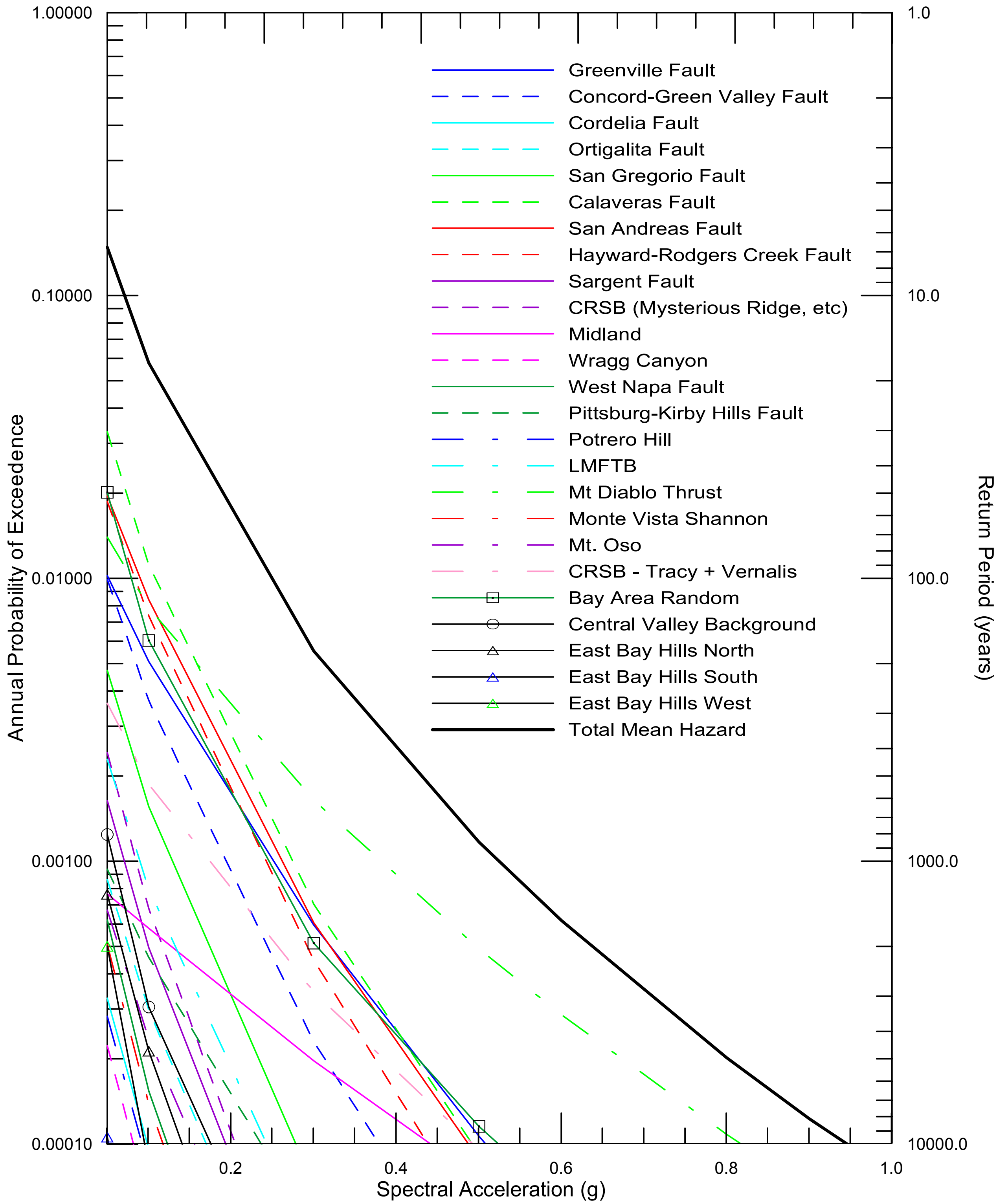
URS	**DELTA WETLANDS PROJECT** IN-DELTA STORAGE FEASIBILITY STUDY	Earthquake Recurrence Relationships Calculated for Seismic Sources (group #1)	Figure 3



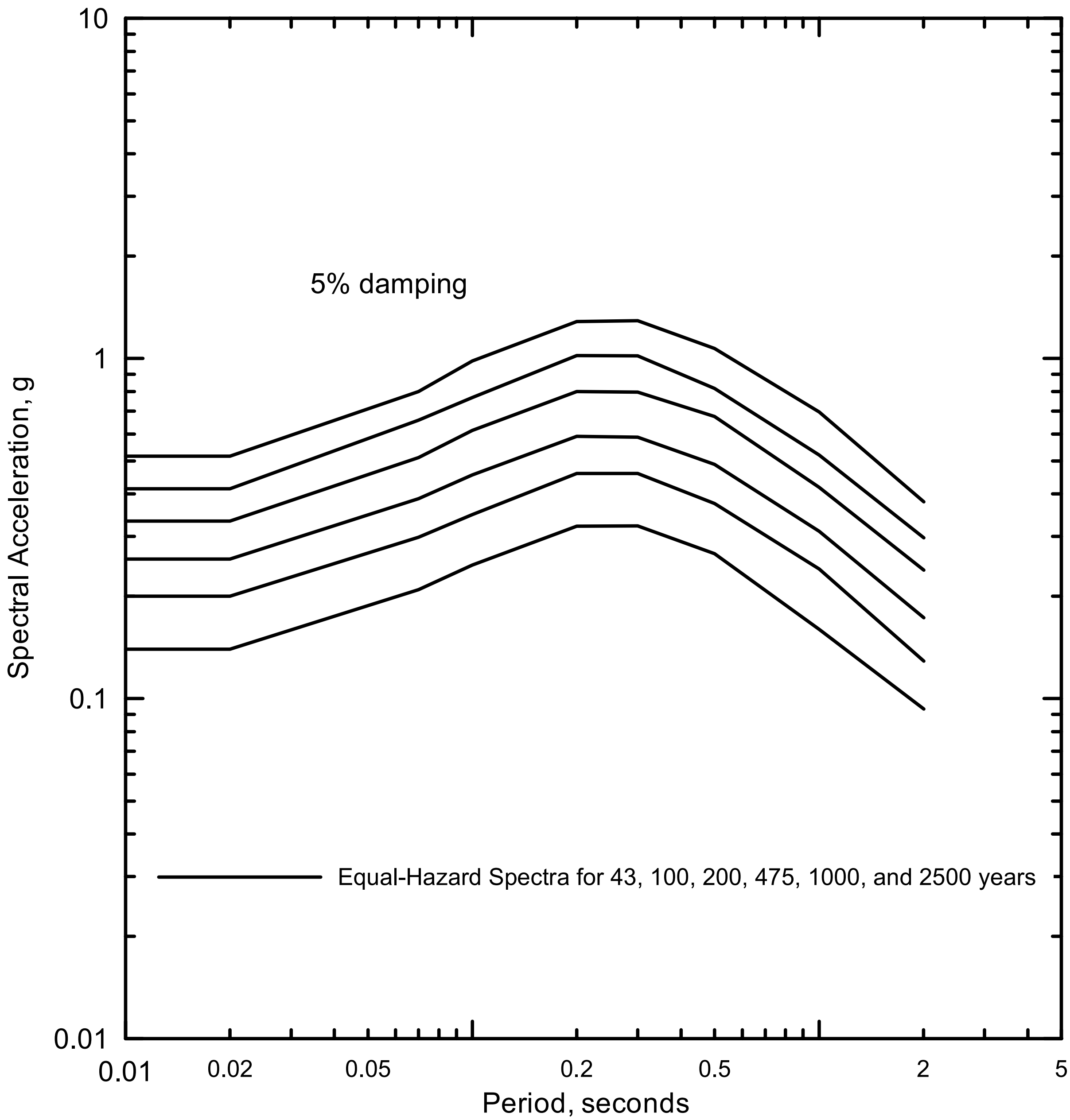
URS	Project # 26814103 **DELTA WETLANDS PROJECT** IN-DELTA STORAGE FEASIBILITY STUDY	Earthquake Recurrence Relationships Calculated for Seismic Sources (group #2)	Figure 4



URS	Project No. 26814105	SEISMIC SOURCE CONTRIBUTIONS TO MEAN PEAK HORIZONTAL ACCELERATION HAZARD	Figure 5
	Delta Wetland Project In-Delta Storage Feasibility Study		



URS	Project No. 26814105 Delta Wetland Project In-Delta Storage Feasibility Study	SEISMIC SOURCE CONTRIBUTIONS TO MEAN 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD	Figure 6



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DELTA WETLANDS PROJECT
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FEASIBILITY STUDY

Equal-hazard Acceleration Response Spectra

Figure 7